THE CYANIDE PROCESS FOR THE EXTRACTION OF GOLD

BY THE SAME AUTHOR

THE METALLURGY OF GOLD: A I
on the Metallurgical Treatment of Gold-bearin
the Processes of Concentration and Chlorinati
ing, Melting, and Refining of Gold. Thi
Enlarged. With 187 Illustrations. Crown 8v

"The whole process of gold milling, from the breaking of
of the bullion, is described in clear and orderly narrativ
not too much, fulness of detail."—*Saturday Review.*

THE METALLURGY OF SILVER
Treatise on the Amalgamation, Roasting, and
Ores. Including the Assaying, Melting, and
Bullion. Second Edition, Enlarged. With
Crown 8vo, 10s. 6d. cloth.

"From first to last thoroughly sound and reliable."—*Co*

THE METALLURGY OF ARGENTIFI
A Practical Treatise on the Smelting of Silver
Refining of Lead Bullion. Crown 8vo, 400
trations, 12s. 6d. cloth.

"The numerous metallurgical processes, which are
embrace all the stages experienced in the passage of the
natural states to its issue as an article of commerce." *Pr*

A HANDBOOK ON MODERN EXPLO
a Practical Treatise on the Manufacture and A
mite, Gun-cotton, Nitro-glycerine, and oth
pounds. With about 100 Illustrations. Crown

"Useful not only to the miner, but also to officers of
blasting and the use of explosives generally may at any ti
auxiliary."—*Nature.*

LONDON: CROSBY LOCKWOOD &

THE

CYANIDE PROCE

FOR THE

EXTRACTION OF G

AND

ITS PRACTICAL APPLICATION ON

WITWATERSRAND GOLD FIEL

IN SOUTH AFRICA

BY

M. EISSLER

[illegible] ENGINEER [illegible] MEMBER OF THE INSTITUTE OF MINING [illegible]

AUTHOR OF "THE METALLURGY OF GOLD," ETC., ETC.

INTRODUCTION.

a great satisfaction to me to be in a position to
before the public, in the present volume, an
nt of the Extraction of Gold by the Cyanide
ss, which I believe will be found by Metal-
ts who desire to avail themselves of the pro-
o be sufficiently full and complete for practical
ses. That I am in a position to do this, is
to the fact of my having made a lengthened
n the Witwatersrand gold fields—whence I
just returned—and to my having enjoyed there
opportunities of studying the process in actual
ion.

means, and in the other chemical means, are employed. I consider the stamping or crushing of the ore in a battery, and the catching of the gold on amalgamated copper plates, a mechanical process, although the recovery of the gold in chemical combination with mercury might entitle it to be considered otherwise. The whole process is nothing more or less than a simple system of concentration, as the gold, owing to its great specific gravity, separates from the lighter gangue in which it is enclosed; and when the pulverized ore particles are washed away, the gold grains sink and are arrested on the amalgamated smooth surfaces of the plates over which the stream carries them, or get entangled in the hairs of the blankets, or are stopped in the riffles of the sluice box, or whatever other method is used in the battery to save the free gold.

When gold is in combination with other minerals, more complicated methods have to be employed to collect it by mechanical means, but these it will be unnecessary to describe in the following pages.

There are very few chemical means by which gold can be won from its ores, leaving aside the smelting process by which the gold is collected in the smelting furnace by means of, and in combination

with, other metals. The reason why gold is not easily won by chemical means is because it is a non-oxidizable metal, which maintains its purity, and is therefore mostly found in its native or metallic state. Owing to its rarity it has become of such great value, and the medium of interchange since the remotest times.

Its solvents are aqua regia, chlorine, and potassium cyanide. The application of such a corrosive agent as aqua regia for the treatment of ores on a large scale is out of the question, and of the chemical means at our command there remain only the last two. By exposing the gold ores, or the concentrated portion of the same, to the action of chlorine gas, the gold is converted into a soluble chloride of gold by the well-known chlorination methods; and by the other method the gold is dissolved in solutions of cyanide of potassium.

That gold when in a fine state of division was soluble in cyanide of potassium, was already known in the middle ages, and the gilding of metals was carried out in those remote days by jewellers and alchemists, by the use of gold in cyanide solutions. Of course, gilding by means of fire was usually employed.

Several scientific books, dating back to the beginning of this century, mention the solubility of gold in potassium cyanide solutions. The application of this solvent for the treatment of auriferous ores was first thought of and patented in the United States in 1867; and although the process was tried and experimented with by some eminent metallurgists of that country, no practical or commercial results were obtained.

Now, how is it—in spite of repeated failure in America and elsewhere—that within the last few years the cyanide process has come into such pre-eminence, and as such a grand success, before the metallurgical world?

In answer to this question, I believe I am safe in stating that the ores of the Witwatersrand gold fields, where the cyanide process was first introduced, carry the gold in a pure and metallic state, in an extremely fine state of division (and even in the pyrites, the gold does not occur in chemical combination, but in a free state); and, therefore, all the conditions existed there to make the application of the cyanide process a perfect success. These facts are not only of interest to the metallurgist, but they should also throw some light on the geological features and conditions under which these peculiar conglomerate beds were formed.

The mines of this district, it should be said, will for ever have to acknowledge the immense services which the MacArthur-Forrest Company have rendered by developing and introducing the process, as they spent large sums to bring it into practical shape, and to demonstrate its commercial advantages. But for those exertions, enormous values would have remained practically unavailable, preventing many mines from working at a profit, and the production of these fields would not be what it is to-day by 50 per cent.

In this connection I can mention that out of a total gold production of 1,478,470 oz. in 1893, there were produced from the tailings 330,510 oz. by the cyanide process; and in August, 1894, out of the monthly production of 174,977 oz., nearly 58,000 oz. were won by the cyanide process.

The great future and potentiality of development which may be anticipated for these gold fields is strikingly illustrated by the opinion of such an eminent authority as Mr. Hamilton Smith, who (in his report to the house of N. M. Rothschild & Sons), has stated that that portion of the Witwatersrand which lies between the Langlaagte Block B and the Glencairn Mine—or about $11\frac{1}{2}$ miles in length, along the strike of the main reef series,—if exploited to a verti-

cal depth of 3,000 ft., would yield in gold 215 million pounds sterling; while Bergrath Schmeisser (in his report made to the German Government), taking for estimate a depth of 800 metres, arrives at the yield of 208 million pounds, and for a depth of 1,200 metres, the yield of 349 millions. And when we consider that at least one-third of these prodigious amounts will be won by the cyanide process, one can hardly overestimate the importance of the work which the MacArthur-Forrest Company has done in bringing that process into its present position of prominence in the Witwatersrand gold fields. Certainly it cannot be gainsaid that they are entitled to a fair reward for their labours.

When I arrived in 1890 on the Witwatersrand gold fields, I undertook numerous experiments for the treatment of tailings by pan amalgamation, but with unsatisfactory results. The difficulty I had to contend with was the formation of large quantities of iron amalgam in the pan. The quicksilver became dirty and floured, causing very heavy losses, and I had a costly process before me to separate the iron from the gold; and although others followed me, and put up various devices for treating the tailings, it was only the advent of the cyanide process which solved this

most difficult problem, as pan amalgamation would have been too expensive.

So far, the process has not achieved similar success in other countries, which to my mind proves that the ores on these fields contain the gold in a free condition; and to further corroborate this view, I can state that at the Simmer and Jack mine the pyritic concentrates which are daily collected on the blankets yield by pan amalgamation 65 per cent. Of course these blanketings contain a considerable amount of free gold which escapes from the copper plates.

Within the last few months, Messrs. Siemens and Halske have successfully introduced on the same fields their patented process, which consists in precipitating the gold by electricity on sheets of lead; and, owing to certain economical advantages, it may be anticipated that their process will prove a formidable rival to its predecessor. In the succeeding chapters will be found an account of the working details of these processes, including some of the observations and researches of those gentlemen who have been most prominent in bringing them to their present state of perfection.

I must not conclude these remarks without expressing my deep obligations to the several gentlemen—

whose names will be found duly recorded in the following pages—to whom I am indebted for much of the material and information embodied in the volume, and for the opportunities so freely afforded me, during my stay in the Witwatersrand gold fields, of making myself practically acquainted with the working of the cyanide process. It is not myself only, but all who are interested—whether as metallurgists or investors—in the gold-mining industry, who have thus been laid under obligation; and as I have taken no small pains to put to good use the material and opportunities which have been so freely placed at my disposal, I trust that the outcome of my efforts in the present volume will prove thoroughly acceptable to that numerous body.

37, Belsize Park,
South Hampstead, London, N.W.
December, 1894.

CONTENTS.

LIST OF ILLUSTRATIONS.

THE

CYANIDE PROCESS

FOR THE

EXTRACTION OF GOLD.

CHAPTER I.

ERECTION OF A CYANIDE PLANT.

Planning the Works.—In the erection of a cyanide plant, before planning the same, some essential points have to be considered. Are the works to be erected to treat an old accumulated stock of tailings? Or have they to be laid out to treat the tailings as they come from the battery? In many cases both these points have to be combined.

As tailings reservoirs are generally situated on the lowest point below the battery site, no provision exists below such dams for the erection of works which would permit of further dumping-ground and handling of the stuff by gravitation. At all events, the topographical conditions of Witwatersrand would allow such an arrangement only in rare instances. In localities where the fall of the ground below the reservoirs permits of the erection of the works, I would recommend this to be done, as it permits of the charging of tanks and their discharging by gravitation. In most cases the opposite course had to be resorted to on these fields; the tailings from the old pits or reservoirs had to be hauled up-hill to the cyanide works, steam power being mostly used. The arrangement is simple enough, as the dumping cars are pulled up on an inclined trestle-work above

the leaching tanks, and after discharging their contents they run back by gravitation, and are held back by the brake of the hauling drum. In large works five to six trucks, holding 20 cubic feet each, are hauled up at a time. At every mine the mechanical arrangement for the filling of the tanks is different, depending on local conditions. Messrs. Fraser and Chalmers have lately introduced a system of mechanical haulage by means of endless wire ropes which works very well, and which I would recommend in preference to anything I have seen on these fields.

To work old tailings by the cyanide process offers no difficulty to percolation, as they come to the works in the proper condition. They were cleaned of the slimes by the natural system of concentration, which takes place in the collecting reservoirs. It is very interesting to stand at the discharge end of the launder carrying the tailings to the reservoir, and to see how the tailings arrange themselves according to the natural laws of gravitation, and are prepared here for subsequent treatment. At the head of the tailing pit the coarser tailings accumulate, and near the dam the finest, and also slimes. The overflow from the first reservoir is collected in a second reservoir, where the slimy, clayey residue accumulates, which, strange to say, is as rich, and even richer, than the tailings in the first reservoir.

To lay out plans for an accumulated stock of tailings offers no great difficulty, provided there is near by a sloping ground permitting of the discharging from the leaching tanks and their dumping by gravitation. If the country is flat, the re-worked tailings will have to be hauled up an incline again and then dumped. On a flat site it will be necessary to place the leaching vats on masonry sufficiently high to give room for discharge, and gradient for the flow of the leaching solutions to the precipitation boxes.

When works are erected to treat tailings which are discharged from the battery, important appliances have to be resorted to, to prepare them for the cyanide treatment, and before they are collected in the leaching vats, owing to the physical condition of the powdered ore.

The discharge launder which carries the tailings from the battery to the cyanide works should have a grade of at least 3 ft. 6 in. in the 100 ft. to insure a good flow. In a flat country where no grade exists, the tailings should be elevated by means of bucket wheels to the proper height. From the experience gained on these fields, tailing pumps have not given satisfaction; it may be that they were not properly constructed, as I am told that in Australia they are in various places in successful operation. There are on several mines here large tailing wheels in use, and I should consider them the best way of elevating tailings, as they require very little attention and repairs when properly constructed and set.

Supposing that we desire to erect a cyanide plant directly behind a battery, the following grade would be required for doing the whole work by gravitation. Supposing the plant to be located 100 ft. from the battery—

	Feet.	Inches.
The grade for the discharge launders will require	3	6
Masonry for settling tanks	6	6
Settling tanks	10	0
Masonry for leaching tanks	6	6
Settling tanks	10	0
Precipitating boxes and grade for outflow pipes	6	0
Total grade	42	6

To this could be added from 6 to 10 ft. of grade for the storage tanks holding the cyanide solutions, wash and alkaline waters, but these are differently placed, and a lack of further grade would present no difficulties, as will be explained later on.

Fig 1 (Plate I.), showing a section of the cyanide plant of the Princess works, illustrates such a mode of arrangement as is here described.

Slimes.—The conglomerates on these fields, after stamping, contain a very large per cent. of slimes. Under slimes are understood the very fine particles of talcose and clayey material mixed with the very fine grains of quartz, iron oxides, and sulphides. If the whole of this fine material be allowed to collect

with the coarser grains, the percolation of fluids through the mass becomes impossible, and, therefore, mechanical means have to be adopted, aiming at a separation of the slimes from the coarser material.

Two methods have been introduced on these fields, aiming at the elimination of the slimes. The one by *direct filling* is the system introduced by Mr. Henning Jennings, the well known mining engineer; and the other *the intermediate filling* adopted by Mr. Charles Butters and Captain Mein, the manager of the Robinson mine.

I will take occasion to remark here that the appliances for the plant were materially changed by Mr. Charles Butters, who has done a great deal for the advancement of the metallurgical treatment of the ores on these fields, as he has introduced a great many practical details, all tending to lessen the cost of the process, and I consider it a very pleasant duty on my part to express my appreciation of his labours and of the good he has done by his work.

The elimination of the slimes has an economic bearing on the gold mining industry of these fields, when it is considered that at least 30 per cent. of the Witwatersrand ores, after crushing, pass away into slime pits: therefore, at the present production of 250,000 tons of ore per month, 75,000 tons go into the slime pits. At the present rate of progress it is almost certain that the tonnage will increase to nearly double this amount, and that within three years the Witwatersrand will be producing 300,000 ounces of gold or one million sterling monthly. If we take the average value of the slimes all around at only 5 dwts. per ton, this represents nearly 20,000 ounces of gold which goes into the pits monthly.

Up to the present no cheap method has been devised to deal with the slimes, so as to win the gold from them at a profit. The question of treating the slimes successfully is simply a mechanical one, as there is no chemical difficulty in the way: on the contrary, the solution of the gold can be easily effected, owing to the fine state of division in which the gold exists in the slimes.

the Witwatersrand conglomerates, I will furnish some figures communicated to me by Mr. Bettel, a gentleman whose name has also been closely connected with the cyanide process.

40 lbs. of tailings were caught at a battery in a tub, and at least 30 per cent. passed away as slimes, the ore coming through a 900 mesh screen. After drying, it was sifted through a screen of 1,600 mesh per square inch, and there remained on the sieve 1·85 per cent. (1)

It passed afterwards through three sieves as follows:

3,600 mesh and there remained on the sieve	27·93 per cent.	(2)
7,225 ,, ,, ,, ,,	20·74 ,,	(3)
14,400 ,, ,, ,, ,,	7·70 ,,	(4)

The sands passing the last sieve were panned, and

A. Remaining in the dish represented . .	11·80 per cent.	(5)
B. Finest sand panned away	22·34 ,,	(6)
C. Slimes collected from the panning water .	7·64 ,,	(7)
Total . .	100·00	

Each of these grades was assayed, with the following results—

1	3·03 dwts. per ton.
2	4·00 ,, ,,
3	4·40 ,, ,,
4	4·65 ,, ,,
5	6·30 ,, ,,
6	2·85 ,, ,,
7	2·85 ,, ,,

These figures are very instructive, as they show how very fine the ore is crushed in a battery, and that the material, after passing through a 120 mesh sieve per linear inch, can be concentrated, and will yield a concentrate of over double the value of the sands washed away. No doubt the practical part of these figures will be very soon appreciated on these fields when concentration will receive closer attention than it does at present.

After this notice of the important part which the slimes

lay in the metallurgy of the Rand gold fields, I will revert gain to the planning of the works.

The Plant.—The main features of a cyanide plant are the ettling vats, the filter vats, the solution storage tanks, and the recipitation-boxes.

The filter vats are made of timber, or they are brick vats ned with cement. At the Langlaagte Estate and Gold Iining Company, circular excavations were made in the ocky ground, lined with bricks and cemented, forming tanks o ft. in diameter and 10 ft. deep, each holding 400 tons of ailings.

Filter vats made of timber will last for years, as contact 'ith cyanide solutions does not seem to destroy it.

I have not been able to obtain the cost of a plant con- tructed in masonry, but I should consider it more expen- ive than the timber plant. Where wooden tanks are in se they are placed in such a position that free access can be ad to the bottoms in case of leakage, which is an advantage.

The number of filtering vats required for a plant depends n the capacity of the battery, and the time it takes to treat a harge of ore. If we want to treat 100 tons of tailings daily, nd it takes, say, 3 days to fill, leach, and discharge a vat, it 'ill require 4 leaching vats of 100 tons capacity each (dimen- ions 22 ft. in diameter and 5 ft. high), but for safety one extra ank is added. The tendency on these fields is to construct a ew large vats for the plant, instead of a large number of small nes. As long as shallow vats were employed, there was no ifficulty in shovelling out the tailings over the sides; but with eep vats the bottom discharge was introduced by Mr. Butters. Before the tailings go to the leaching tanks they have to be 'eed of their slimes, and I shall now describe the two methods dopted for this purpose.

Intermediate Filling. Messrs. Butters and Mein's Distributors.—The first attempts at intermediate filling were nade by running the battery tailings to the centre of a circular

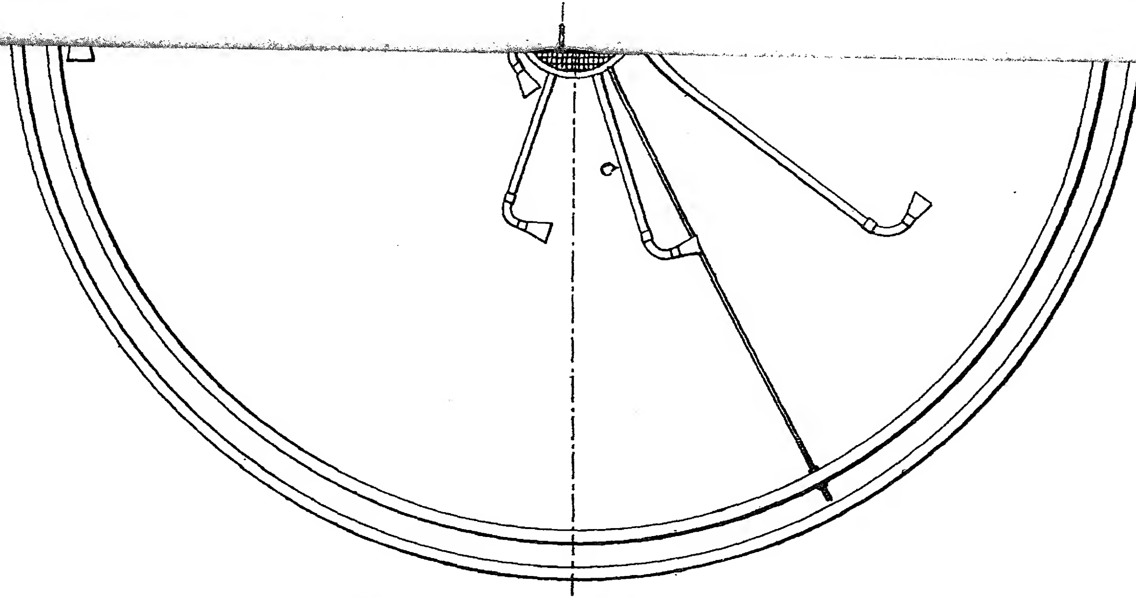
vat, and allowing the overflow to take place at one point. This did not prove successful, because the sand piled up in a central conical heap, and the slimes settled in the deeper water around the sides of the tank. The next plan was to run the pulp into the vat through a series of stationary launders, delivering at several fixed points. This method improved the distribution, but the result was still unsatisfactory. Then, in order to give an uniform overflow at every point of the periphery of the vat, a circular trough was fixed round the top to collect the overflow and deliver it to a launder.

Each of these alterations was a step in the right direction, but the system of settling could not be considered successful until after the introduction of an automatic revolving distributor. This appliance consists of a central casting, with a vertical spindle A revolving in a footstep bearing B, which casting carried a conical hopper E and a number of radial pipes C with bent ends, as shown in section in Figs. 2, 3 (Plate II.), and 4 and 5.

The distributor is fixed on an iron column in the centre of the vat. The bends at the end of the pipes cause the apparatus to revolve by the reaction of the pulp as it leaves the pipes. Each pipe has a different length, in order to distribute over a number of concentric circles. This also has its faults, as it was found that the slimes collected in narrow rings between the outlets of each pipe, giving rings of clean sand alternately with rings of slime. The difficulty was overcome by attaching flattened nozzles to the ends of the pipes, causing the pulp to spread over a wider area, and also by increasing the number of pipes.

As is noticed by this plan, the arrangement is a hemispherical bowl from which radiate 8, 12, to 16 pieces of pipes of various length, which is set in motion by the centrifugal action of the discharging water, something similar to a garden sprinkler, only that it revolves slowly. The bowl is covered with a coarse screen so as to prevent chips or leaves to enter and choke the pipes. The diameter of the discharge pipes is $1\frac{1}{2}$ to $2\frac{1}{2}$ in.

PLATE II.



Figs. 2 and 3.—Messrs. Butters and Mein's Automatic Distributor.

[To face p. 8.

It is necessary to fill the vat with clean water before admitting the pulp. If this is not done, the water is practically stationary, and a constant settlement of slimes takes place until the vat is full and the overflow begins, in which case the tailings in the lower part of the vat will always be more slimy than those in the upper part. For the same reason it is essential that the overflow be continuous until the vat is full of sand; for if any stoppage takes place slime settlement in excess occurs, and a complete layer of slime is formed across the vat which prevents the overlying sand from draining dry. Therefore, when the battery is stopped, an equal quantity of water should be supplied to the vat. When the pulp is admitted into the tank previously filled with water, the light slime remains in suspension and overflows into the annular ring which surrounds the tank at the top, and from the discharge opening is carried by a launder to the slime-pit.

When the vat is filled with tailings, the outlet pipe below the filter is opened and the water allowed to drain off, the draining taking about fifteen to twenty-four hours. When holes are dug down to the discharge doors, water again commences to flow from the outlet, consequently it is advantageous to dig these holes about six hours before the discharging.

One very important matter is the proper size of vat to be used for a given tonnage crushed in the battery. It is, of course, desirable to catch as large a quantity of slimes with the sands in the tailings as is possible without rendering the product unleachable. When the vats are too small they carry away too much fine sand with the slime; and if they are too large they catch too much slime, which settles in excess. The great difficulty to overcome yet with these intermediate vats is to get the last foot or two near the bottom properly drained, and if discharged and transferred to the leaching tanks in this wet condition, the excess of moisture dilutes the cyanide solution.

To facilitate and hasten the leaching, various devices have been adopted. At the Princess works, where the ground is steep, the drainage pipe has been extended down to the reser-

voir, thereby causing a natural suction. At the Simmer and Jack works the drainage pipe is connected with a steam exhaust acting like an ejector, so as to cause a vacuum below the filter, and thereby the rate of leaching is increased. At the Worcester works the vats catch from the crushed ore from 75 to 80 per cent. of good leachable tailings, containing 12 per cent. moisture after draining eighteen to twenty-four hours.

The following are the sizes of the intermediate vats erected at some of the works:—

Meyer and Charlton Gold Mining Company, treating 120 tons per day, has 4 vats, each 20 ft. in diameter and 8 foot staves.

Pioneer Gold Mining Company, treating 70 tons daily, has 2 vats, each 20 ft. in diameter, and 14 foot staves.

Worcester Gold Mining Company, treating 70 tons daily, has 2 vats, each 20 ft. in diameter, and 8 foot staves.

Princess Gold Mining Company, treating 85 tons daily, has 2 vats, each 20 ft. in diameter, and 7 foot staves.

The Robinson Gold Mining Company, treating 330 tons per day, has 6 vats, each 24 ft. in diameter, and 11 foot staves.

When all the pulp is running into 1 vat, only about 66 per cent. of the crushed ore is caught, but the whole of this is clean sand and drains sufficiently. If, however, the total pulp from the battery was run into 2 vats, about 80 per cent. of the crushed ore, instead of 66 per cent., would be obtained from the distributing tank. After the water has been leached out, the ore is discharged through bottom discharges into trucks and taken to the leaching tanks. In some localities the distributing tanks are on a higher level than the leaching tanks, and the trucks are then run by gravitation to the leaching tanks. At some works the distributing tanks are at lower level than the leaching tanks, and then the trucks have to be hauled up by steam power.

The framework of the tram lines on which the trucks are hauled up to the leaching tanks rests inside the tanks and on the masonry foundation, and at large works there is generally a

double line of rails on top of the tanks. The vats and storage tanks are in the open, and not covered by a building.

The following are the advantages of intermediate filling, as introduced by Mr. Charles Butters*:—

1. It is claimed that, by means of Mr. Butters' distributor, from 75 to 80 per cent. of sands, both coarse and fine, with some slimes, are collected in the intermediate tanks, the bulk of the slimes escaping with the effluent water, which is practically free from sands.

2. The water is drained off as near as possible, and when the intermediate vat is discharged through the bottom discharges, the sands during the operation get thoroughly mixed up, thus being in the best condition for treatment by cyanide.

3. Oxidation of pyrites is very slight, so that very little cyanide will be consumed.

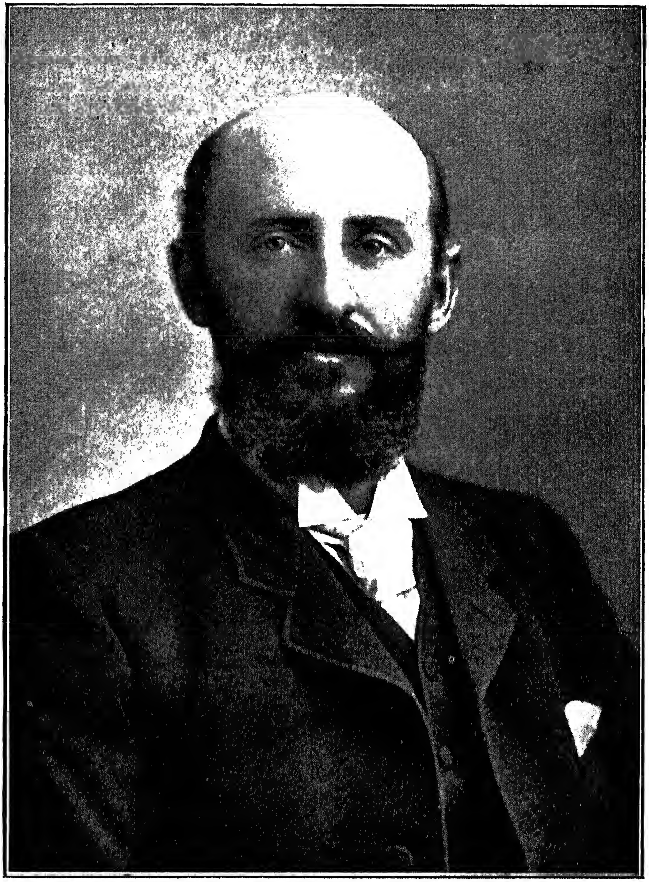
To an impartial observer it would appear that the system of intermediate filling would commend itself as the one which is more practical, as the tailings undergo, so to say, a special preparation for the subsequent lixiviation. The expense of transferring the tailings from the intermediate tank to the leaching tank is so slight that it cannot be considered as an important item.

The cost of charging tailings and discharging the residues has been brought down at the Robinson Mine to 10d. per ton of 2,000 lbs., and generally stands in the accounts of other works at about 1s.

Messrs. Butters & Mein's Distributors are constructed in three sizes according to the following particulars:—

Size A Distributor has 8 distributing pipes, all of $1\frac{1}{4}$ in. diameter, and is the size of distributor used on batteries up to 30 stamps.

* The position held by this gentleman in the Witwatersrand gold fields is so influential, that the accompanying portrait will be of great interest to many readers of this book; and I have great pleasure in inserting it here, if only to emphasise my sense of the acknowledgment due to Mr. Butters in regard to the information and assistance so freely afforded to me when collecting materials for this volume.—M. E.



MR. CHARLES BUTTERS.

[To face p. 12.

Size B has 12 distributing pipes—6 of 2 in. diameter, 2 of 1½ in. diameter, and 4 of 1¼ in. diameter—and is the size of distributor used on batteries of from 30 to 70 stamps.

Size C has 16 distributing pipes—2 of 2½ in. diameter, and 14 of 2 in. diameter—and is the size of distributor used on batteries of from 60 to 120 stamps.

The above sizes of distributors have been calculated on the average crushings per stamp for the Rand.

Direct Filling.—This method, introduced at the works of the Heriot, City and Suburban, Crown Reef, Paarl Central, and Geldenhuis Estate companies, consists in passing the pulp as it leaves the plates into a *hydraulic separator*, a kind of crude spitzlutte. The pulp is here divided into two streams, one overflowing, carrying slimes with very fine sands; the other, consisting of coarse sands, some fine sands and slimes, which are conveyed by means of an india-rubber hose to the leaching tanks, in which one or more Kaffirs are employed to effect the even distribution of the pulp, by moving the hose about to different parts of the vat. The water passes off by adjustable gates fitted inside the vats, carrying with it fine sands, slimes, and some coarse sands. The advantages of the process are:—

1. This method treats pyritic tailings with the minimum of oxidation, as they are not exposed to the action of the air from the time they leave the battery.

2. A second handling of the tailings before treatment is avoided.

3. A preliminary rough concentration, or rather classification of the coarser particles of the tailings is effected.

There is at present a great controversy going on regarding the advantages of direct filling as against intermediate filling, and according to Mr. Bettel the disadvantages of the process are:—

"1. The tailings pack tightly in the vat, and consequently do not drain completely, and a diffusion of the first cyanide

solution which is applied takes place at the commencement of leaching, causing loss of cyanide and gold. At the Crown Reef works I noticed that the distribution seemed to be pretty regular, and drainage can be assisted by means of exhaust pumps.

"2. The distribution of the sands and slimes is not so even, and some sands escape treatment, being protected by impervious layers of slime, the cyanide naturally escaping by the paths of least resistance. In leaching tanks where an uneven distribution of slimes and sands takes place, the slimy portion will not drain off; and on discharging such a tank, it is easily noticed that the streaks of slime are saturated with moisture and are still gold bearing, whereas the sandy portion has the solution drained off. The importance of an even distribution and mixture of the pulp can hardly be estimated.

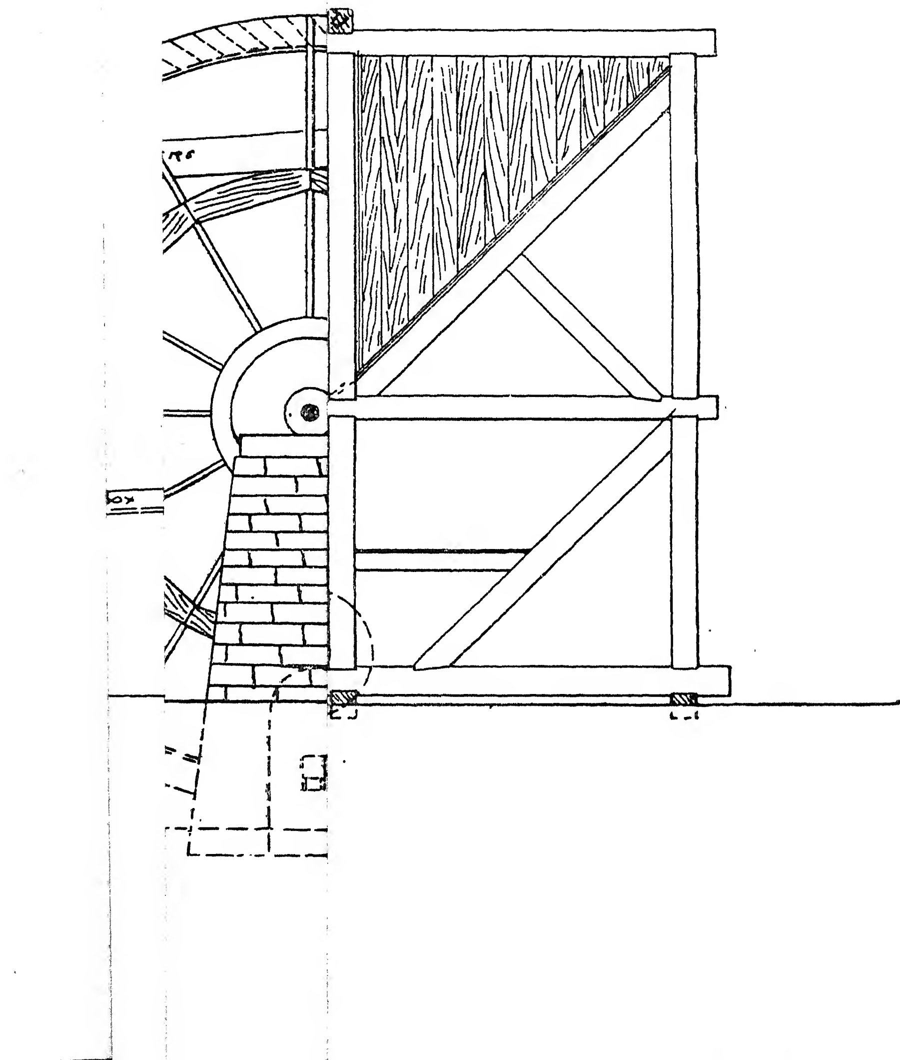
"3. At most of the works where direct filling is introduced, square cement tanks are employed, and the discharging of these is not so practical as the wooden ones fitted with bottom discharges."

In Plate III. (Fig. 6), the tailing wheel, vanner room, and cyanide vats at Jumpers' mine are shown in section.

The Filter or Leaching Tanks.—These are, in most instances, made circular, that form being the strongest. They are from 20 to 42 ft. in diameter, and from 8 to 14 ft. in height, and should be constructed of well-seasoned lumber, with staves 3 to 4 in. thick, having their inner and outer faces cut to correspond to the arc of circle of the tank, and their edges radial to this circle (Fig. 7). The staves are not tongued or grooved, the pressure of the hoops being sufficient, if the tank is well made, to make them perfectly tight. The staves should be at least 1 ft. longer than the inside depth of the tank, and gained from 1½ in. into the bottom timbers, with a chime of several inches.

The bottoms are made of 3 by 9 in. deals, tongued and grooved (Fig. 8), and put together with white lead, or litharge and glycerine. The hoops should be made by wrought iron

PLATE III.



[To face p.

rods from $\frac{3}{4}$ to $1\frac{1}{2}$ in. in diameter, according to the size of the tank, with threaded ends passing through wrought iron lugs and tightened by hexagonal nuts. When the tanks are of large diameter these hoops are made in sections. The outside of the tanks can be painted in lead paint.

The bottoms of the vats rest on wooden beams 6 by 9 in., placed 18 in. apart. These beams are placed across the stone

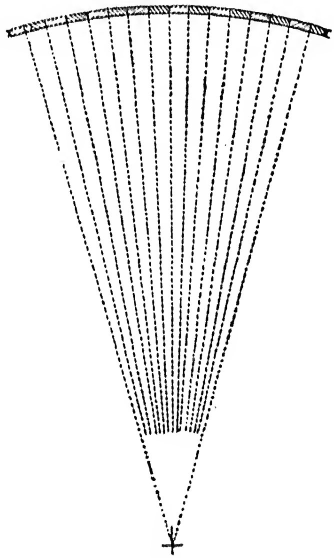


FIG. 7.—STAVES CUT TO CIRCLE.

foundation, and rest in their turn on planks $1\frac{1}{2}$ by 11 in. The planks are put between the stone foundation and the beams to merely ensure a perfectly level surface.

The construction of these vats should not be entrusted to the hands of any other workmen than experienced coopers.

It is obvious that tanks holding such enormous weights should rest on good foundations, and in every case where

wooden foundations have been used the result has been t
the tanks settled, got out of plumb, and leakages occurred.

The filters are constructed of wooden slats, 1½ by 4
set 12 in. apart, fastened to the bottom by wooden pi
Grooves ¾ in. deep and 3 in. wide are cut in a number
places in the bottom of these slats to allow a free passage of
solution along the bottom. On top of these slats are laid str

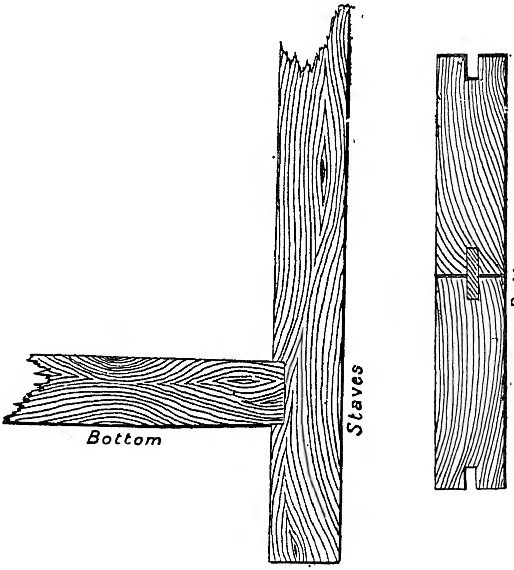


FIG. 8.—CONSTRUCTION OF FILTER VATS.

of wood 1 by 1 in., only 1 in. apart from each other, maki
openings 1 in. square. Between the ends of this wooden gra
ing and the inside of the tank an annular space of about 1½ i
wide is left, which is partly filled by a strip of wood 1 in. thic
bent to the circle of the tank. Over this and the slats
placed cocoa-nut matting and burlap, and held by a rope ½ i
in diameter, which is driven into the space remaining betwe

the strips of wood and the staves of the tank. On top of the matting are laid again slats of wood 1 by 3 in., parallel one to the other, about 6 in. apart, their object being to protect the matting from being injured when shovelling the tailings through the man-holes into the trucks below.

The stone foundations are usually 6 ft. 6 in. high above the level of the rails, and are composed of a series of walls closed at their ends, leaving one or two passages underneath for the trucks (Fig. 9).

Each leaching vat has a separate drain pipe, 1 to 2 in. in diameter, and these pipes are so arranged in the extractor house, as to lead the strong solution to the strong extractor box

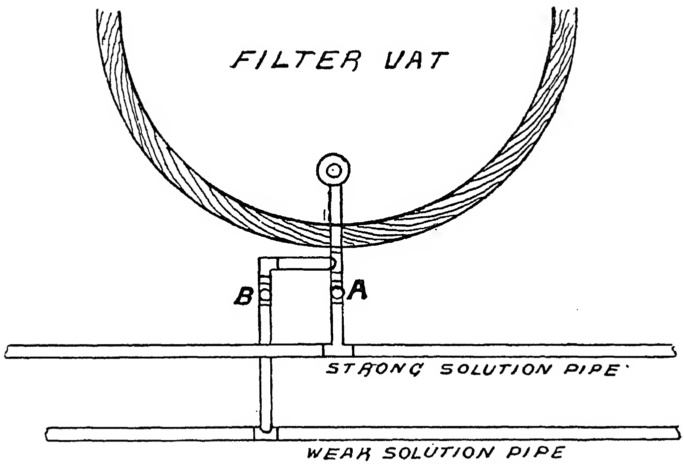


FIG. 10.—SOLUTION PIPES.

and the weak solution to the weak extractor box. In some works there is one main collecting drain pipe for strong solution and one for weak solution, and the connections are shown in Fig. 10. By shutting the valve, A, leading to strong collecting pipe, and opening valve, B, leading to weak collecting pipe,

the flow is regulated. Filtration is best assisted by causing a vacuum under the filter bed; by connecting the drain pipe with a steam pipe and passing a jet of steam through the same, a vacuum is created under the filter bed.

I should also mention that the best and cheapest method of discharging the tailings from the leaching vats is to sluice them out from a side door, but for this purpose a stream of running water is required, which on these fields is not available.

Mr. Feldtmann * describes a system of discharging tailings from the leaching vats through a bottom discharge door into a launder, whence a copious stream of water carries the residues into the creek below.

The discharge doors can also be made on the side of the vat when the residues are to be sluiced out.

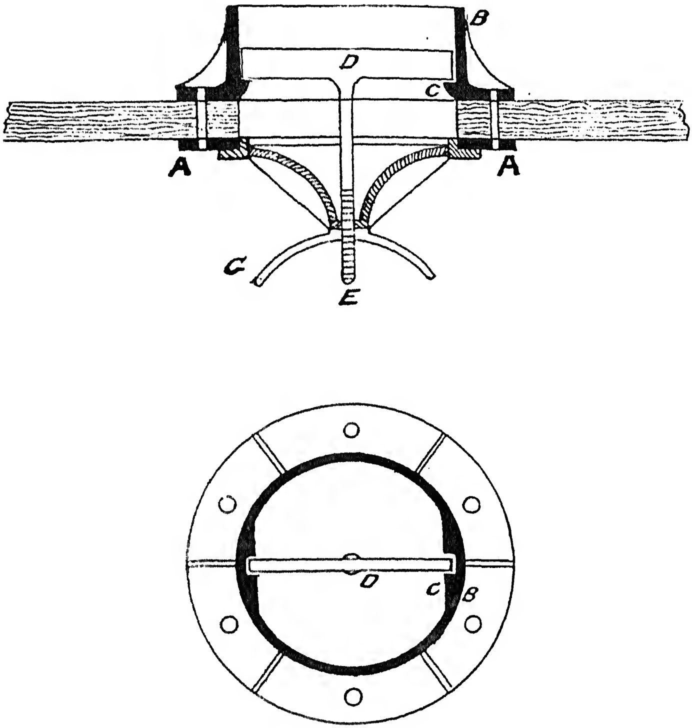
The round wooden filter vats on these fields are discharged by bottom discharge doors, which are closed by means of Butters' discharge lids. According to the size of the vats, there are two, four, six, or eight of these discharge openings to each vat.

Figs. 11, 12 show the arrangement. On the bottom side of the tank a cast-iron ring, A, is bolted to the cast-iron cylinder, B, inside the tank. Inside the cylinder is the projecting lug, C, upon which rests the hanger, D, which forms part of the screw, E; the cast-iron cover, when placed in position, is simply fastened by the nut, G, and, screwing the same firmly, the whole arrangement becomes water-tight. The faces of the ring and the cover should be planed, so as to make a good joint. There are other methods of closing the discharge openings. When a tank is to be filled, a clay luting is given inside the iron cylinder, and then the same is rammed full with tailings. When filling the tank with tailings, especially into deep vats, a length of 3 to 4 ft. pipe is put over the discharge holes, and then the tailings are dumped in. It will be easily understood that in discharging a deep tank it facilitates the running of the tailings into an outlet if the same is within a few feet of the surface,

* "Notes on Gold Extraction." Argus Printing and Publishing Co., Johannesburg, 1894.

instead of having to push them down 13 or 14 ft. by means of long poles.

The cocks and valves should be of iron.



FIGS. 11, 12.—BUTTERS' DISCHARGE LID (SCALE 1 IN. = 1 FT.).

Pumps.—Several varieties of pumps are used to raise the solution from the sumps to the lixiviation tanks, and to provide circulation if needed. Centrifugal pumps are mostly used on these fields.

Stock Solution Tanks.—There are generally three solu-

tion tanks at each plant, built very much the same as the leaching tanks, with the exception that they have no filters, man-holes, &c. They are of different capacity, according to the size of the works, and are required to be of sufficient dimensions to store enough solution to keep the works going, without having to run any to waste.

Inside the tanks are gauges indicating the volume of solution. The stock solution tanks are usually 20 ft. in diameter, and from 7 to 14 ft. in height. One is for strong, one for weak solution, and one for alkaline wash. Every foot in height in a 20-ft. tank represents 10 tons of solution of 2,000 lbs. per ton.

To calculate the cubic contents of a circular tank, the following formula is employed. Multiply the square of the radius 10^2) with 3·14, and the product by the height of tank (6 ft.).

$$10^2 \times 3{\cdot}14 \times 6 = 1884 \text{ cubic feet.}$$

1 cubic foot of water weighs 62·3 lbs. Therefore,

$$1884 \times 62{\cdot}3 = 117573 : 2000 = 58{\cdot}78 \text{ tons of water.}$$

If we desire to prepare a 0·3 per cent. stock solution,

$\frac{117573{\cdot}2 \times 0{\cdot}3}{100} = 352{\cdot}71$ lbs. of cyanide will have to be dissolved in it, making allowance for any impurity in the cyanide. After treatment we find that the solution analyses only 0·16 per cent. Consequently, by multiplying

$\frac{117573{\cdot}2 \times 0{\cdot}16}{100} = 188{\cdot}11$ lbs. is left in the solution; and to make the same up to 0·3 per cent., another 164·61 lbs. of cyanide will have to be added.

Zinc Precipitation Boxes.—These are made of 1 to 2 in. boards, and are oblong boxes of various dimensions, which have to be in proportion to the quantity of solution which passes through them. In large works, the boxes are 20 ft. or more in length, 3 ft. high, and 3 to 4 ft. wide. There are separate boxes for the strong and for the weak solutions to pass through. At most works there are four of these boxes, placed in what

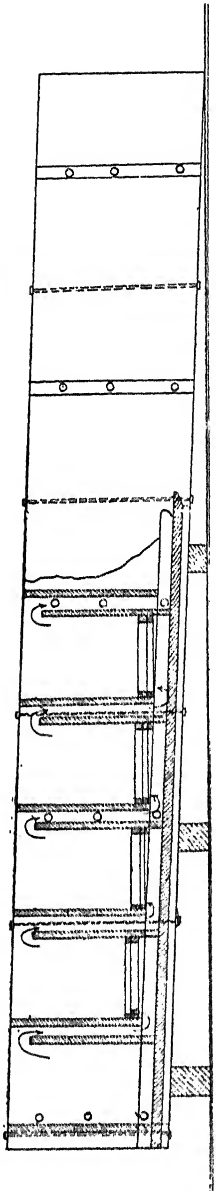


Fig. 13.—Zinc Precipitation Box.

is called the extractor-house, which also contains the machinery, pumps, furnaces, &c.

The precipitation-box is divided into several compartments by partitions and baffle boards, in such a way that the solution is forced to flow upward through the zinc shavings, which are held in trays several inches above the bottom of the troughs. Fig. 13 shows the construction of the troughs.

The first division has not got any zinc shavings in the same, as here the solution enters, and any sediment or fine slime which may have passed through the filter settles here. If any intermediary settling tanks are used, as at the Worcester works, this first compartment can be utilised also to hold zinc shavings. From the first compartment the solution flows over the partition, and then down the space, and upward through the tray holding the zinc shavings. The baffle-board is held in place in the position shown in the drawing by being nailed fast to the sides, and reaches a few inches above the level of the solution. From this explanation it becomes clear that the solution has to pass its downward and upward course till the last partition is reached, and from here passes through a pipe to the collecting sump or tank.

The zinc box compartments are fitted with removable trays, made of

wooden frames supporting wire screen of ⅛-in. mesh. The gold in the solution settles on the zinc as a brown coating, and which soon, as it accumulates in a finely powdered state, falls through the screens to the bottom of the trough. In the last partition of each box there is no zinc, but the tray here is utilised to hold cyanide of potassium in lumps to make up its standard strength before pumping the same into the storage tanks.

Over the zinc there is placed a light wooden grating, and the whole trough can be covered by a strong wire netting to secure against theft, as the same can be kept under lock and key.

At some works a wooden launder, covered with a lid and also under lock and key, is attached longitudinally to the box, and from each compartment in the trough when a clean up is made, a plug is withdrawn and the slimes which have accumulated in the bottom are washed through the launder on to a filter and collected. In most works, the clean-up is made differently, as described later on. The zinc trays rest on cleats, several inches above the bottom, and have handles on the sides so that they can be easily lifted out when cleaning up. After passing through the precipitation-boxes the solution is pumped back to the storage tanks, and is used continuously and not run to waste. The dissolved zinc does not accumulate in the stock solution to a great degree, and is probably precipitated in the lixiviation tanks with the charges of fresh ore.

CHAPTER II.

EXTRACTION BY CYANIDE.

Synopsis of the Process.—On the Witwatersrand gold fields, the cyanide process has been mainly adapted to the re-treatment of the tailings. As the largest proportion—and amongst it the coarser particles of gold—have been extracted by previous plate amalgamation, the precious metal in the tailings is in a very fine state of division, and therefore amenable to cyanide treatment. It must be here remarked that the coarser the gold, the longer it takes to dissolve it; and it is recommendable, therefore, that all ores should be first submitted to plate amalgamation before submitting them to the cyanide treatment.

When the first cyanide works were erected on these fields, the old accumulated stocks of tailings had to be dealt with. Owing to their long exposure to the atmosphere, changes had taken place in their chemical composition, which caused at the onset some difficulties, but these were soon overcome on the application of the proper remedies. The ores which came from the upper levels, or the oxidized zone, always carry a small proportion of iron pyrite, which, on exposure, becomes oxidized. It is only when free milling ore tailings are taken directly from the battery to the cyanide works that they do not